USB Active Cable Thermal Compliance Test Specification

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CONTENTS

1 USB Active Cable Thermal Compliance Test

USB active cable assemblies shall meet or exceed the requirements specified by the most current version of Section 6.5.1 of the Universal Serial Bus Type-C Cable and Connector Specification.

1.1 Temperature Definition

1.1.1 Ambient Temperature Measurement T_A

The ambient temperature shall be measured in the approximate horizontal plane adjacent to plug under test. The temperature sensor shall be placed a minimum of 15 cm from any heating sources to be least affected by heat affects from air convection. It should not be placed right above any heating elements to stay away from convection "plume". If possible, place two to four temperature sensors in different locations of the chamber and take an average. See Figure 2 and Figure 3 for example location of ambient temperature sensors. T_A in this test is required to be within 20 ˚C to 25 ˚C.

1.1.2 Surface Temperature Measurement T_S

Identify maximum temperature location (top side and bottom surface) of the plug with the assistance of thermo-image, or infrared (IR) camera. To obtain maximum surface temperature reading by IR camera, please select proper emissivity for housing material. It is not recommended to use IR camera for this measurement if housing surfaces are highly reflective such as polished metal surfaces. Attached a type K 36 AWG thermal couple to the maximum temperature location by thermally conductive epoxy. The maximum surface temperature is most likely to be on the plug surface near the main active component such as the repeater.

1.2 USB Active Cable Thermal Test Setup

Figure 1 USB Active Cable Thermal Test Setup Up

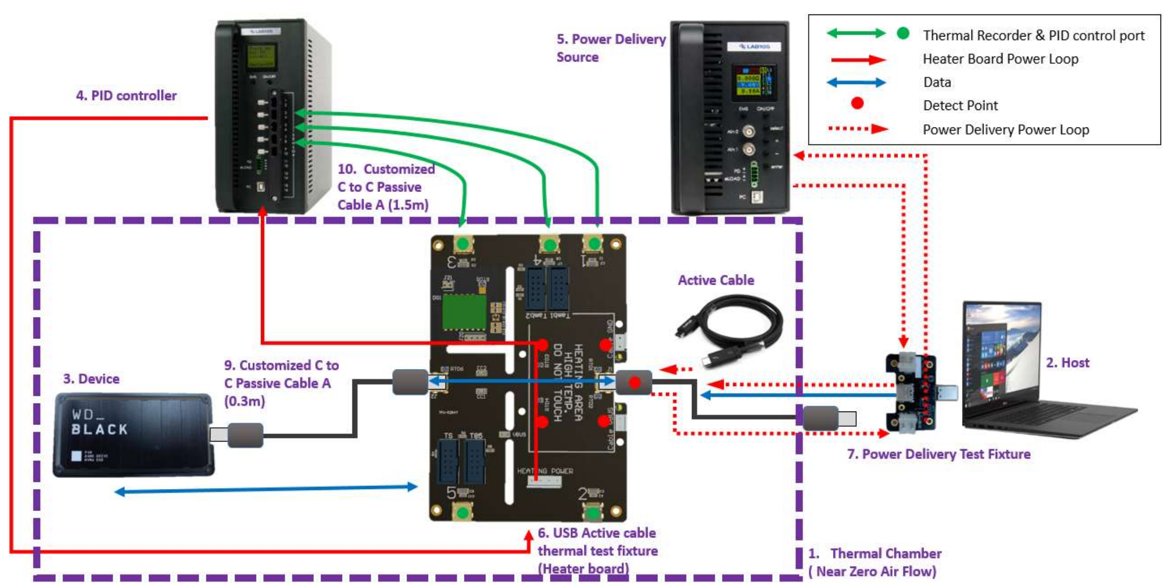


Figure 1 shows the active cable thermal test setup and the **Table 1** lists the equipment required in this setup.

Table 1 USB Active Cable Thermal Test Equipment

	Item Name	Equipment Manufacturer	P/N	Notes
1	Thermal Chamber	N/A	N/A	1. Near zero air flow 2. Absolutely Min. size: 0.5m (H) x 0.6m (W) 0.6 m (D)
2	Host	N/A	N/A	Version higher than USB3.2 Gen2*2
3	Device	N/A	N/A	Version higher than USB3.2 Gen2*2
4	PID Controller	LUXSHARE-ICT	PID100-ASSY	Customized design
5	Power Supply and E-load	LUXSHARE-ICT or equivalent	PD100-ASSY	Supply up to 5A current to Power Delivery circuit
6	USB Active Cable Thermal Test Fixture (Heater Board)	LUXSHARE-ICT	TFU-52R4T	Customized design
7	Power Delivery Test Fixture	LUXSHARE-ICT	TF04-700J	Customized design for injecting 5A PD current externally
8	RTD Cable	LUXSHARE-ICT	CCUB-ATA-0P	Customized design
9	Customized C to C Passive Cable A 1.5 m	LUXSHARE-ICT	CCUB-ATB-0P	1. Required quantity: 5 2. Customized Type C Cable
10	Customized C to C Passive Cable B 0.3 m	LUXSHARE-ICT	CCUB-ATH-0A	Customized Type C Cable
11	Flexible Heater for Thermal Shutdown	LUXSHARE-ICT	CCUB-ATR-0P	Customized design
12	Adjustable Power Supply	LUXSHARE-ICT	TEUB-ADT-0A	1. Manual or Programmable 2. Customized design

1.2.1 Thermal Chamber

The thermal test chamber tries to achieve a "zero airflow" environment (Beaufort Number near 0) for this test. The cable shall be placed in an enclosure that shields them from external movements of air. If an enclosure is used it shall be walled with non-reflective material. It shall have a non-reflective cover. The enclosure or room shall be of sufficient size to accommodate any test cable spacing as described herein. The thermal chamber shall be able to maintain the internal temperature to be within +/- 1 degree Celsius.

Plug shall be in free air suspension. Plug shall be arranged in a horizontal attitude and shall meet the following requirements:

Plug shall not be closer than 20 cm minimum from the walls of the enclosure or closer than 25 cm minimum from the top of the enclosure or shall be a minimum of 5 cm minimum above the bottom of the enclosure. See **Figure 2** and **Figure 3** for set up minimum dimensions in an enclosure.

Figure 2 Top View of Thermal Environment (Not to Scale)

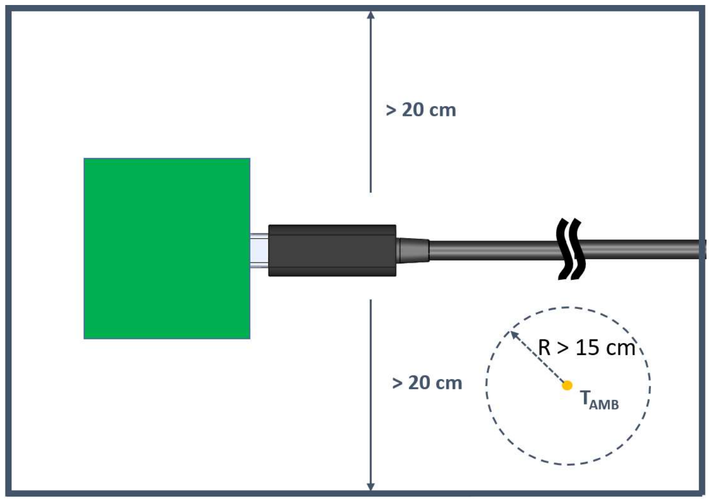
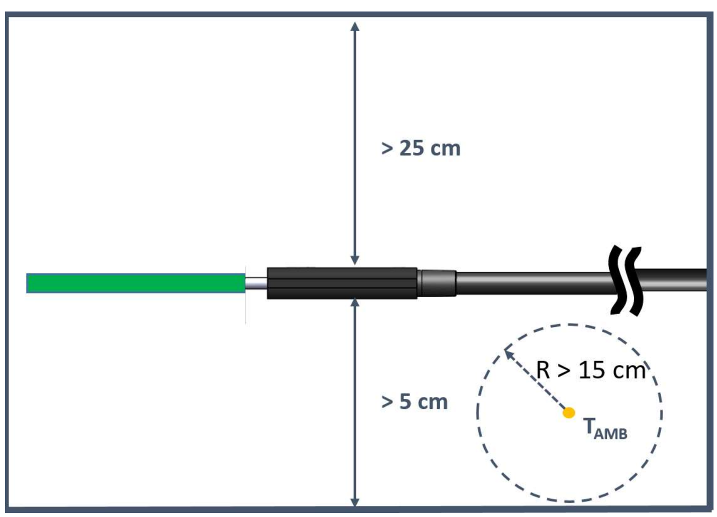


Figure 3 Side View of Thermal Environment (Not to Scale)



1.2.2 Host

Host is on the source side. It shall come with USB Type C port and it shall support data speed higher than USB3.2 Gen2x2.

1.2.3 Device

Device is on the sink side. For example, a Solid-State Drive (SSD) can be used to sink high speed data. It shall come with USB Type C and it shall support data speed higher than USB3.2 Gen2x2.

1.2.4 USB Active Cable Thermal Test Fixture (Heater Board)

USB Active Cable Thermal Test Fixture is part of the passive transmission link of the Device Under Test (DUT). It is also a heater board that serves as thermal boundary for an active cable assembly to simulates a real user scenario when a cable is plugged into a mother board. Board heating power is supplied by PID controller (section 1.2.5) connected to the 4-pin header.

Heat board supports two types of RTD sensors for temperature feedback:

- Six surface mount type RTD sensors: RTD1 thru RTD6. These are six temperature measurement points at different locations on the heater board. The power supplied to the test fixture is determined by the four temperature readings from RTD1 thru RTD4 near the DUT cable receptacle. Four temperatures are defined as T_{B1}, T_{B2}, T_{B3}, and T_{B4}.
- Four plug-in type RTD sensors: T_{A1} and T_{A2}. The board also serves as the data acquisition of See section 1.2.8.

The ten analog signal inputs from the RTD sensors are passed onto the PID controller (section 1.2.5) thru five data ports (Type C receptacles) on the edge of the test fixture. Each port carries two signals. See section 1.2.9 for details of the connection cable.

Figure 4 USB Active Cable Thermal Test Fixture

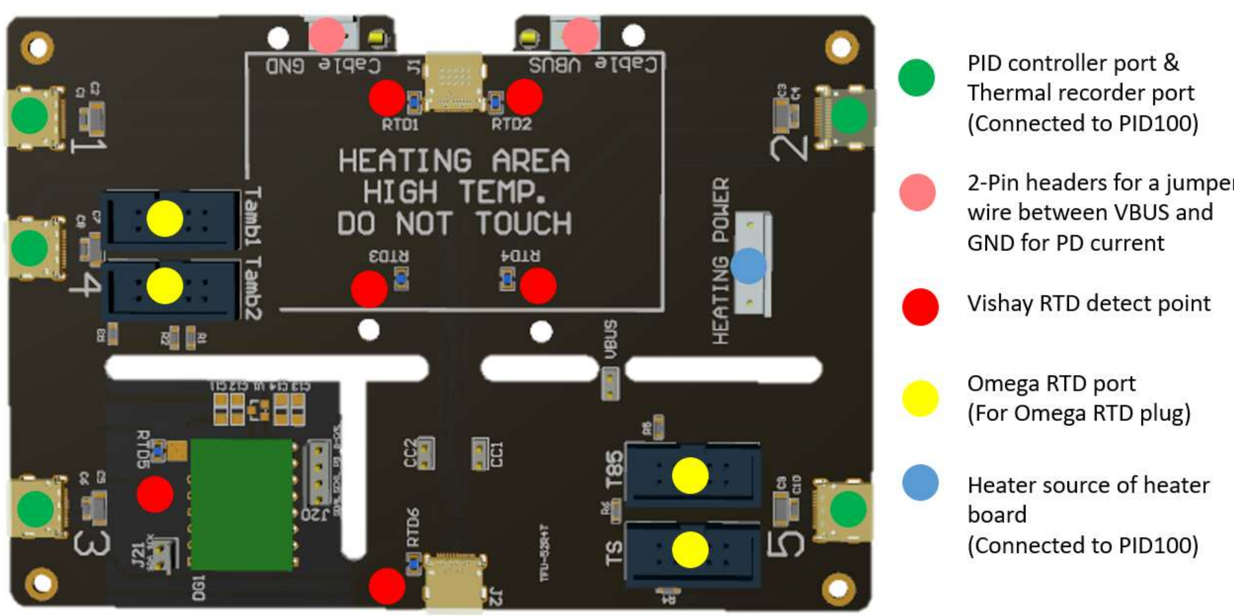


Table 2 RTD Sensors on Thermal Test Fixture

Sensor Number	Function	Sensor PN
RTD1	Heater board heat area detect	Vishay-PTS0805M
RTD2	Heater board heat area detect	Vishay-PTS0805M
RTD3	Heater board heat area detect	Vishay-PTS0805M
RTD4	Heater board heat area detect	Vishay-PTS0805M
RTD5	Engineer Use	Vishay-PTS0805M
RTD6	Engineer Use	Vishay-PTS0805M
T_{A1}	Ambien temperature	OMEGA-SA1-RTD-4W-120
T_{A2}	Ambien temperature	OMEGA-SA1-RTD-4W-120
T_{S1}	Plug surface temperature 1st end	OMEGA-SA1-RTD-4W-120
T_{S1}	Plug surface temperature 2nd end	OMEGA-SA1-RTD-4W-120

1.2.5 PID controller

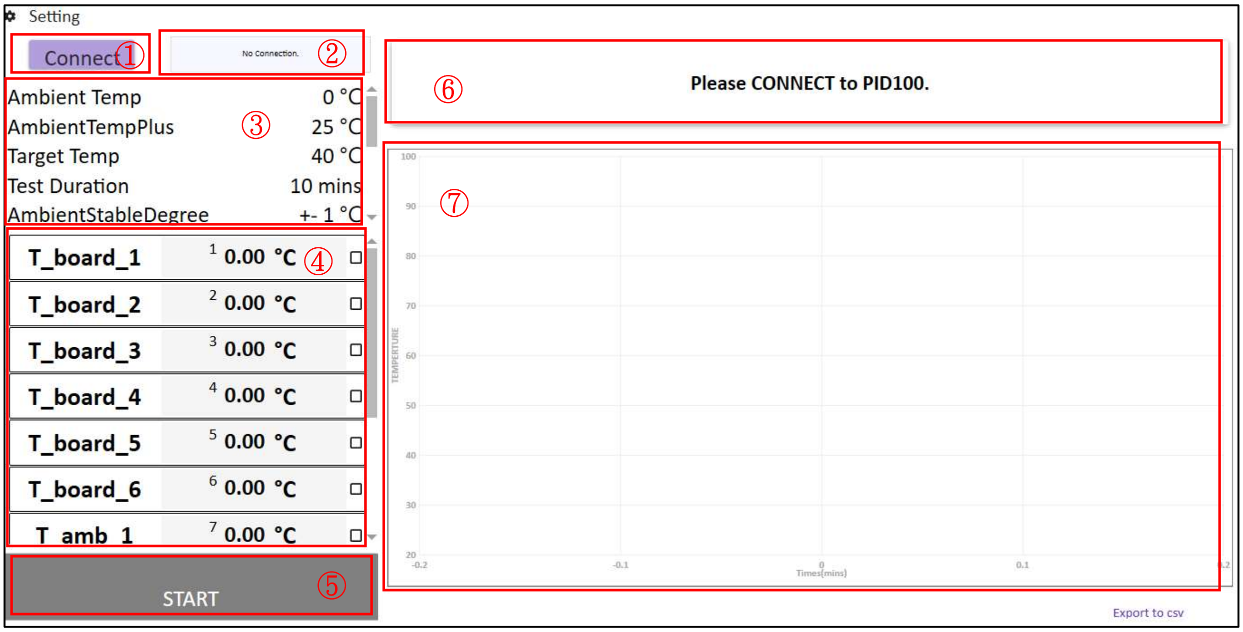
PID100 is a PID controller that is specifically designed to heat up the USB Active Cable Thermal Test Fixture (also called the Heater Board). It consists of a current source to heat up the heater board by a 4-pin connector and it takes inputs from the ten RTD sensors thru five customized type C to type C passive cables. PID100 has a built-in full color LED display for user convenience (**Figure 5**).

PID controller holds accuracy within +/- 0.5°C in close state, and within +/- 1.0°C in open state. Maximum temperature variation is less than 0.5℃ from PID close state and PID open state (refer to **Figure 17**).

Figure 5 PID controller

The data of temperatures from the RTD sensors can be displayed and collected by a data acquisition (DAQ) software package (XXX.zip). It can be unzipped and used on any windows computer. PID100 exports the data through a USB port to the PC. **Figure 6** shows the DAQ software interface and lists the functions of each panel.

Figure 6 PID100 DAQ Software Interface



① Button to connect PID100 to the host
② Connection Status Indicator
③ Thermal test condition setting
④ Display of RTD temperature reading in Celsius
⑤ Button to start testing
⑥ Display next step of the test
⑦ Real time thermal characteristic in display

1.2.6 Power Delivery Source and E-load

The PD100 is an integrated power supply and E-load unit designed specifically to supply up to 5 A current for cable Power Delivery (PD) in USB active cable thermal test. It injects Power Delivery current through Power Delivery Test Fixture into the DUT cable. Current options are 0.5 A, 1 A, 2 A, 3 A, 4 A, and 5 A; voltage options are 3.3 V, 5 V, 9 V, 12 V, 15 V, and 20 V.

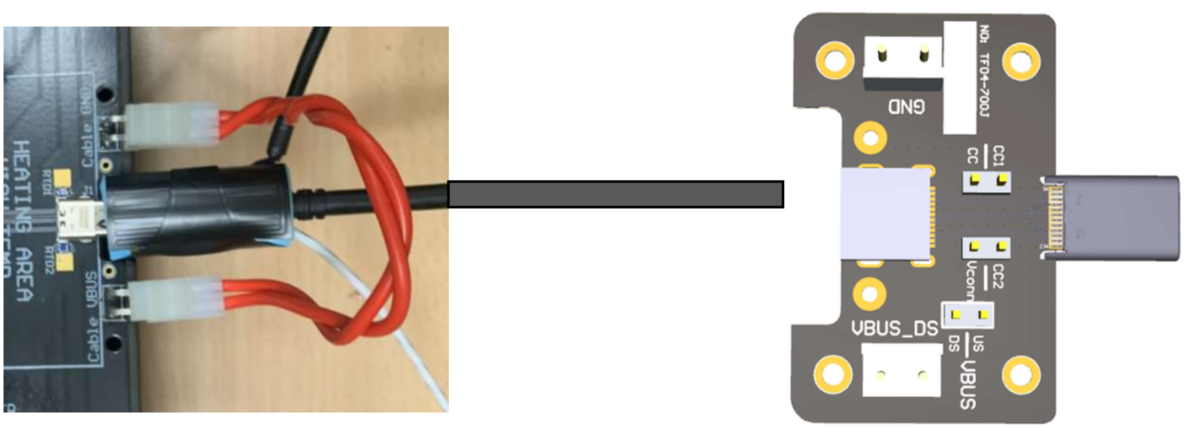
Note: PD100 unit can provide up to 5 A current and this is sufficient for either SPR or EPR cable. As in thermal testing, the heat induced by the PD circuit depends on the current going through the cable rather than voltage. Thus either 100 W (20 V/5 A from legacy the specification of PD 3.0) or 240 W (48 V/5 A from the specification of PD 3.1) can be tested with the PD100 unit.

Figure 7 Power Delivery Source and E-load Unit

1.2.7 Power Delivery Test Fixture

Power delivery test fixture is placed between host and DUT cable to facilitate the injection of the PD current. Power Deliver Source PD100 (section 1.2.6) provides the PD current up to 5A. It flows from PD100 to the VBUS connector of the PD test fixture, through the DUT cable, then the jumper wire of the Heater Board, and loops back to the DUT cable and out of the GND connector of the PD test fixture. The jumper wire connects the two 2-pin headers near the Type-C receptacle of the DUT cable on the Heater Board.

Figure 8 Power Delivery Test Fixture



1.2.8 RTD Sensor Cable

Four RTD sensor cable (PN: RTD-4W-120 by Omega) are plugged in onto the heater board:

- Two for ambient temperature: T_{A1} and T_{A2};
- Two for the two ends of DUT cable plug surface temperature: T_{S1} and T_{S2}.

Figure 9 RTD Sensor Cable

1.2.9 Customized USB C to C Passive Cable A (Length: 1.5 m)

This is a customized design for USB Active Cable Thermal Compliance Test only. It is for temperature data transfer and communication between RTD sensors on Heater Board and PID controller. There are five of these for ten RTD signals. Its wire connection follows **Table 3**.

Figure 10 Passive Cable A (Length: 1.5 m)

1.2.10 Customized USB C to C Passive Cable B (Length: 0.3m)

This is a customized cable that connects the Thermal Test Fixture and the device. It uses regular USB Type-C connectors, but its wire connection is different than a regular passive cable. Each pin of one end of cable plugs simply pass through the signal to the other end of cable plug. Its wire connection follows **Table 3.**

Figure 11 Passive Cable B (Length: 0.3 m)

Table 3 RTD Customized USB C to C Passive Cable B Wire Connection Table

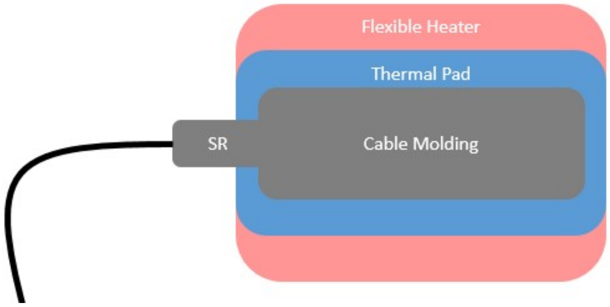
P1		Cable Wire	P2	
Plug Pin	PCB PIN	Wire AWG	PCB PIN	Plug Pin
A1, B1, A12, B12	GND	Drain	GND	A1, B1, A12, B12
A4, B4, A9, B9	VBUS	22 AWG Red	VBUS	A4, B4, A9, B9
A5	CC	Red	CC	A5
B5	Vconn	Blue	Vconn	B5
A6	D+	Green	D+	A6
A7	D-	White	D-	A7
A2	TX1+	Orange	TX1+	A2
A3	TX1-	Brown	TX1-	A3
B11	RX1+	Blue	RX1+	B11
B10	RX1-	Black	RX1-	B10
B3	TX2-	Green	TX2-	B3
B2	TX2+	White	TX2+	B2
A10	RX2-	Purple	RX2-	A10
A11	RX2+	Yellow	RX2+	A11
A8	SBU1	Yellow	SBU1	A8
B8	SBU2	Black	SBU2	B8
Shell	Shield	Shield	Shield	Shell

1.2.11 Flexible Heater for Thermal Shutdown Test

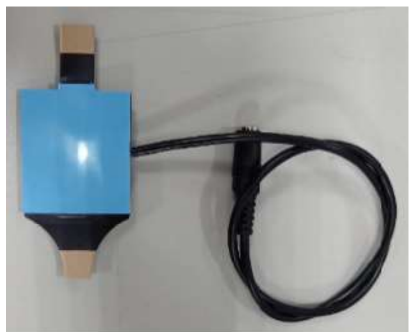
Flexible heater is used for thermal shutdown test. According to ***USB Type C Spec R2.1 Section 6.5 Active Cables Thermal Specification***, the Thermal Shutdown Skin Temperature of the overmold shall not exceed T_{SHUT} Celsius degree. That is, when skin temperature is over T_{SHUT}, the data transmission would be terminated, and the cable plug is shut down.

Flexible heater is made of a flexible layer of heating element bonded with thermal conductive layer and it is used to be wrapped around the cable plug. It comes with a 3.5 mm power jack, and it is plugged into a power supply.

Figure 12 Flexible Heater



(a) Cross Section Illustration



(b) Flexible Heater with Thermal Pad Attached on One End, and a Power Jack on the Other End

1.2.12 Adjustable DC Power Supply Adapter for Thermal Shutdown Test

An adjustable power supply adapter is used for thermal shutdown test. It plugs into AC 110 V and the power jack plugs into the flexible heater described in section 1.2.111.2.11. It provides a range of output voltages to it by adjusting the reading on the adapter.

Figure 13 Adjustable DC Power Supply

1.3 Test Software

Test software is installed on a PC that connects to PID controller. Please refer to the section of software from PID100 User Operation Manual PID100-V2.

1.4 Test Procedures

1.4.1 Surface Temperature

To test the surface temperature of the active able, set up the active cable thermal test following **Figure 1.**

1. Verify electrical function of the test fixture works by plugging in a DUT active cable.
   a. Verify high speed link has been established by available software. Check source and device link state. An example of such software is shown in **Figure 14**:

Figure 14 Example of Software for Checking High Speed Link

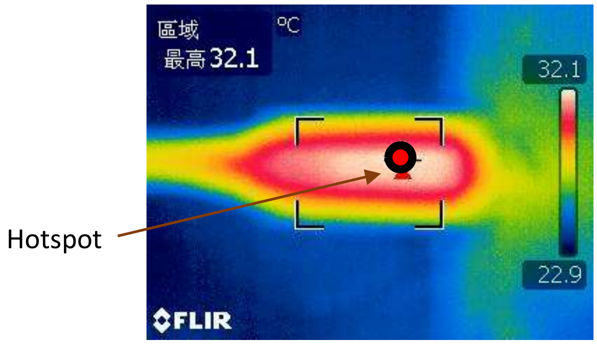
(a) USB Device Detected

(b) HS Link State Software Example

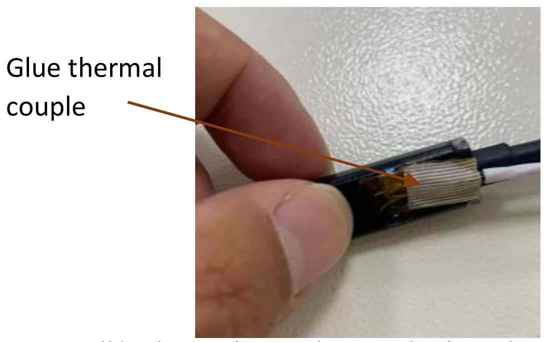
   b. Check power delivery current loop is working properly.

2. Attach RTD sensors for surface temperature measurement referring to **Figure 15**:
   a. Identify the hotspot on plug overmold surface of one end of the cable by infrared camera.
   b. Glue thermal couple (RTD) on the hotspot, and this is the max surface temperature T_{S1};
   c. Repeat step a. and step b. on the plug of the other end of the cable, this is T_{S2};

Figure 15 RTD Sensor Location for Surface Temperature Measurement



(a) Hotspot Identified on IR Image



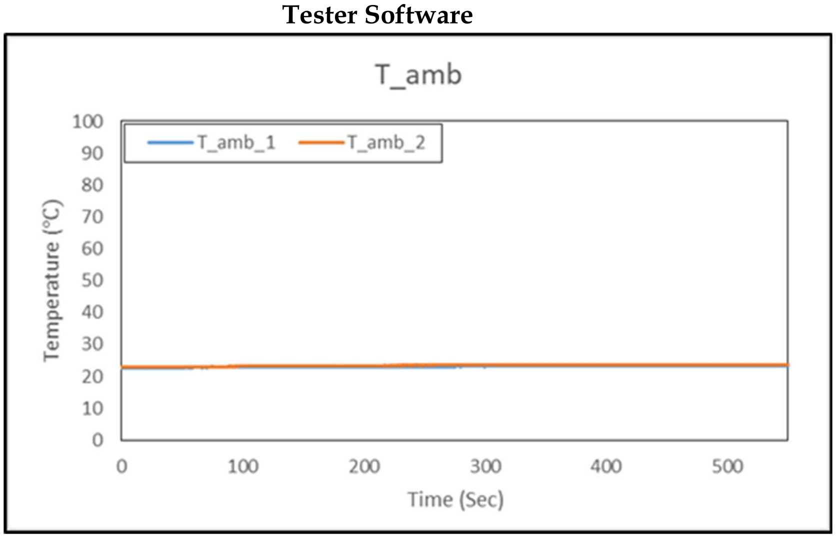
(b) Thermal Couple Attached on the Hotspot

3. Install the PID100 Thermal Tester software on a PC that connects to PID controller.
4. Wait until ambient temperature stability is achieved. Verify T_A is within 20 ˚C to 25 ˚C.

b. Set chamber temperature the same as room Ambient Temperature T_A. This helps to reduce the ambient temperature variation caused by outside environment when chamber door opens.

c. Measurement shall be performed with no airflow condition at ambient temperate T_A. It is stabilized when T_A stays within +/- 1°C for more than 1 min.

Figure 16 Example: Ambient Temperature Stabilized within 23 °C +/-1 °C on PID100 Thermal Tester Software



d. Plug in active DUT cable onto heater board inside the chamber. Do not plug in the other end to the host yet.

e. Close the chamber.

5. Prepare thermal boundary to target of (T_A +25°C)

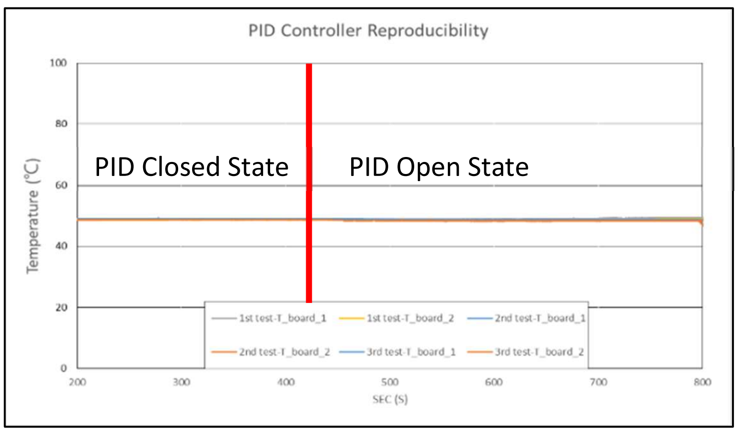
   c. PID controller is set at state of loop back (default);

   d. Controlled thermal boundary temperature by turning on heating elements and wait until thermal stability is achieved. Thermal boundary stability is defined when a minimum of three consecutive readings of (TB1, TB2, TB3, and TB4) taken at one-minute intervals maximum does not differ by more than +/-1°C for each measurement points.

   e. When thermal stability is reached, break the closed loop of the PID control. Software will prompt for PID open loop. An example of the transition from closed loop to open loop is shown on **Figure 17**(a).

   f. Temperature change as PID100 switches from close loop to open loop must not exceed +/-0.5°C. See **Figure 17**(b) for a few test examples of the temperature change acceptable. This is to guarantee a consistent thermal boundary.

Figure 17 PID Switches from Closed Loop to Open Loop



(a) PID Closed Loop Broken while Thermal Stability is Maintained

	Max. Δ (℃)
First Test	0.33
Second Test	0.49
Third Test	0.49

(b) Temperature Change from Closed Loop to Open Loop

6. Plug in the other end of the active cable into the host outside of the chamber and verify high speed link is established. Set up the power delivery current at specified maximum rating.

a. High speed data transfer is higher than USB3.0 Gen 1;

b. Power delivery is set to maximum specification: 60W (20V, 3A) for SPR cable, or 240W (48V, 5A) for EPR cable.

7. Wait until thermal stability is achieved and record all temperatures measurements at the same time.
   a. All of sensors detected on the same time. Their data are displayed in time on the main window of the DAQ software (**Figure 6**);
   b. T_{B1}, T_{B2}, T_{B3}, and T_{B4} are the four sensors next to the active DUT cable receptacle for monitoring;
   c. PID integrated thermal recorder sends outputs to the test software on the PC and displays all of the eight measurements: T_{S1}, T_{S2}, T_{B1}, T_{B2}, T_{B3}, T_{B4}, T_{A1} and T_{A2}.
8. Pass and Fail Criteria:
   a. Refer to ***USB Type-C Specification Release 2.1, Section 6.5.1.2 (Active Cable Thermal Specification) and Table 6-15*** for cable temperature requirements.

1.4.2 Thermal Shutdown Test (Informative)

Thermal shutdown is a requirement for USB Active Cable address in USB Type-C Spec R2.0 section 6.5.1. However, the compliance test is currently not required.

The test fixture and the following procedures are ready to be used for an applicable cable with thermal shutdown function. To test the thermal shutdown temperature of the active able, set up the active cable thermal test following **Figure 1.**

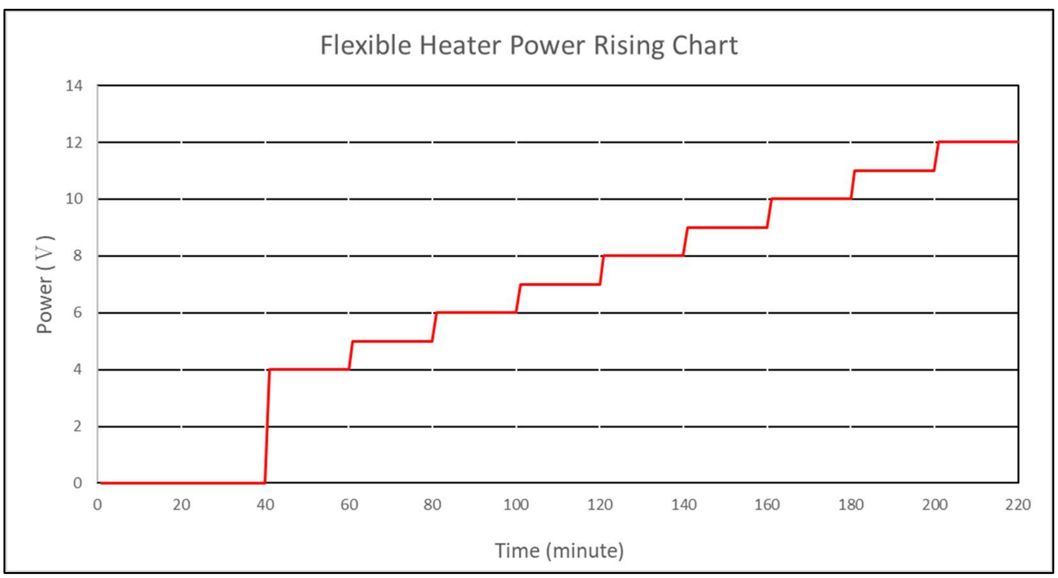
1. Verify electrical function of the test fixture works by plugging in a DUT active cable.
   a. Verify high speed link has been established by available software. Check source and device link state. Refer to **Figure 14**.
   b. Check power delivery current loop is working properly. Refer to **Figure 8**.
2. Attach RTD sensors onto plug surface and wrap flexible heat around the plug.
   a. Identify the hotspot on plug overmold surface of one end of the cable by infrared camera referring to **Figure 15** (a);
   b. Glue thermal couple (RTD) on the hotspot, and this is the max surface temperature T_{S1} referring to **Figure 15** (b);
   c. Repeat step a. and step b. on the plug of the other end of the cable, this is T_{S2};
   d. Wrap flexible heater tightly around cable plug of the DUT cable. This is done for thermal shutdown test. The wrapping is done before tests start to avoid the air flow change caused by opening the chamber door.

Figure 18 Plug Overmold Wrapped with Flexible Heater for Thermal Shutdown Test

Thermal shutdown test step 3 through step 7 are exactly the same as step 3 through step 7 in Section 1.4.1

9. Heat up the Flexible Heater per heating profile in **Figure 19**
   a. Monitor T_{S1} temperature of the plug wrapped under the flexible heater. When the reading stays within +/- 1°C for more than 1 min., connect Flexible Heater to the adjustable DC power supply adapter.
   b. Turn on the Flexible Heater. The initial reading is at 4 V (near 0.5 W) by default.
   c. Starting from 4 V, voltage increases 1 volt for every 20 minutes, until it reaches 12 V. The power output at the starting point of 4 V is close to 0.5 W and is about 3.3 W at 12 V.

Figure 19 Thermal Shutdown Flexible Heater Heating Profile



10. Continuously monitor T_{S1} temperature by PID100. Acquire data through PID100.
11. Repeat step 3 through step 9 on the plug of the other end with surface temperature of T_{S2};
12. Pass and Fail Criteria:

a. Refer to ***USB Type-C Specification Release 2.1, Section 6.5.1.2 (Active Cable Thermal Specification) and Table 6-15*** for cable temperature requirements.

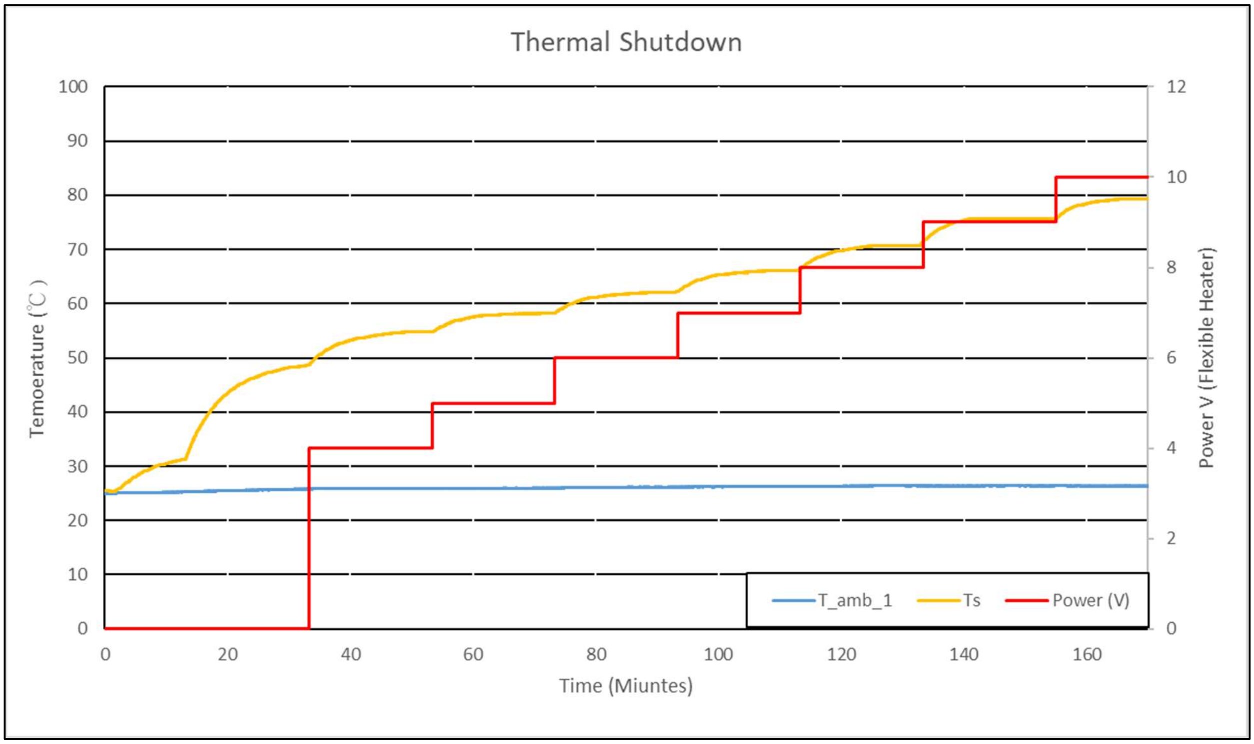
b. The cable data link shall **shut down** when surface temperature surpasses Thermal Shutdown Skin Temperature ($T_{S1} > T_{SHUT}$ and $T_{S2} > T_{SHUT}$). If so the cable **passes** Thermal Shutdown Test.

c. If the cable does **NOT shut down** when surface temperature surpasses Thermal Shutdown Skin Temperature ($T_{S1} > T_{SHUT}$ and $T_{S2} > T_{SHUT}$), the cable **fails** Thermal Shutdown Test.

d. If and only if both plugs pass, the cable **passes** the Thermal Shutdown Test.

e. Considering the reading and system errors, cable shutdown temperature is allowed to be within +/- 1°C of the specified Thermal Shutdown Skin Temperature T_{SHUT}.

Figure 20 Example of a Typical Active Cable with a Plastic Overmold that Failed to Thermally Shutdown at 77 ˚C



Thermal shutdown measurement in ***Figure 20*** shows that as heating power increases, the surface temperature T_S of the plug under test also increases. When T_S exceeded 77°C, this specific cable kept running and did NOT shut down. When T_{SHUT} criteria is set at 77°C, this cable would fail. Alternatively, if a cable shuts down when it reaches 77°C, then it would pass the test.

Figure 21 Example of a Typical Active Cable with a Plastic Overmold that Succeeds to Thermally Shutdown at 77 ˚C

Figure ***21*** shows that an active cable with a plastic overmold successfully shut down as heating power increases and the surface temperature T_S of the plug reaches over the Thermal Shutdown Skin Temperature T_{SHUT}.